

# Common Markets, Strong Currencies & the Collective Welfare

Esteban Guevara Hidalgo<sup>†‡</sup>

<sup>†</sup>*Center for Nonlinear and Complex Systems, Università degli Studi dell'Insubria, Via Valleggio 11, 22100 Como, Italy*

<sup>‡</sup>*SIÓN, Autopista General Rumiñahui, Urbanización Edén del Valle, Sector 5, Calle 1 y Calle A # 79, Quito, Ecuador*

The so called “globalization” process (i.e. the inexorable integration of markets, currencies, nation-states, technologies and the intensification of consciousness of the world as a whole) has a behavior exactly equivalent to a system that is tending to a maximum entropy state. This globalization process obeys a collective welfare principle in where the maximum payoff is given by the equilibrium of the system and its stability by the maximization of the welfare of the collective besides the individual welfare. This let us predict the apparition of big common markets and strong common currencies. They will reach the “equilibrium” by decreasing its number until they reach a state characterized by only one common currency and only one big common community around the world.

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## I. INTRODUCTION

In recent works [1, 2, 3, 4, 5, 6, 7] the relationships between quantum mechanics and game theory were analyzed. Starting from the fact that a physical system is modeled through quantum mechanics (and/or physics) and a socioeconomical one through evolutionary game theory was shown how although both systems are described through two theories apparently different both are analogous and thus exactly equivalents.

That produced interesting results (like the quantum analogue of the replicator dynamics, the quantization relationships for classical systems, the quantum games entropies, the thermodynamical temperature of a socioeconomical system, the collective welfare principle and the quantum understanding of classical systems) and strange interesting consequences like the analyzed in the following research.

The so called “globalization” process (i.e. the inexorable integration of markets, currencies, nation-states, technologies and the intensification of consciousness of the world as a whole) has a behavior exactly equivalent to a system that is tending to a maximum entropy state.

This globalization process obeys a collective welfare principle in where the maximum payoff is given by the equilibrium of the system and its stability by the maximization of the welfare of the collective over the individual welfare. This let us predict the apparition of big common markets and strong common currencies. They will reach the “equilibrium” by decreasing its number until they get a state characterized by only one common currency and only one big common community around the world.

## II. RELATIONSHIPS BETWEEN QUANTUM MECHANICS & GAME THEORY

The clear resemblances and apparent differences between both theories and between the properties both enjoy were a motivation to try to find an actual relationship between both systems. In the next table we compare some characteristic aspects of quantum mechanics and game theory.

Table 1

Quantum Mechanics	Game Theory
n system members	n players
Quantum States	Strategies
Density Operator	Relative Frequencies Vector
Von Neumann Equation	Replicator Dynamics
Von Neumann Entropy	Shannon Entropy
System Equilibrium	Payoff
Maximum Entropy	Maximum Payoff

To find an actual relationship between quantum mechanics and game theory lets analyze more deeply both systems.

### A. Quantum Statistical Mechanics & the von Neumann Equation

#### 1. Description of a Physical System

A physical system is described through a Hilbert space where a state of that system is described through a state vector (element of that Hilbert space)  $|\Psi(t)\rangle$  which is postulated that contains all the information of the system. An ensemble is a collection of identically prepared physical systems. When each member of the ensemble is characterized by the same state vector  $|\Psi(t)\rangle$  it is called pure

ensemble. If each member has a probability  $p_i$  of being in the state  $|\Psi_i(t)\rangle$  we have a mixed ensemble. Each member of a mixed ensemble is a pure state and its evolution is given by Schrödinger equation. To describe correctly a statistical mixture of states it is necessary the introduction of the density operator  $\rho(t) = \sum_{i=1}^n p_i |\Psi_i(t)\rangle \langle \Psi_i(t)|$  which can be expressed in matrix form. The density operator contains all the physically significant information we can obtain about the ensemble in question. Any two ensembles that produce the same density operator are physically indistinguishable. The diagonal elements  $\rho_{nn}$  of the matrix which represents the density operator  $\rho(t)$  represents the average probability of finding the system in the state  $|n\rangle$  and its sum is equal to 1. The non-diagonal elements  $\rho_{np}$  expresses the interference effects between the states  $|n\rangle$  and  $|p\rangle$  which can appear when the state  $|\Psi_i\rangle$  is a coherent linear superposition of these states.

## 2. Evolution of a Physical System

The time evolution of the density operator is given by the von Neumann equation

$$i\hbar \frac{d\rho}{dt} = [\hat{H}, \rho], \quad (1)$$

where  $\hat{H}$  is the Hamiltonian of the physical system. The von Neumann equation is only a generalization (and/or a matrix-operator representation) of the Schrödinger equation and the quantum analogue of Liouville's theorem from classical statistical mechanics.

## B. Evolutionary Game Theory & the Replicator Dynamics

### 1. Description of a Socioeconomical System & the Notions of Equilibrium

Game theory [8, 9, 10] is the study of decision making of competing agents in some conflict situation. It tries to understand the birth and the development of conflicting or cooperative behaviors among a group of individuals who behave rationally and strategically according to their personal interests. Each member in the group strive to maximize its welfare by choosing the best courses of strategies from a cooperative or individual point of view.

Evolutionary game theory [11, 12, 13] does not rely on rational assumptions but on the idea that the Darwinian process of natural selection [14] drives organisms towards the optimization of reproductive success [15]. Instead of working out the optimal strategy, the different phenotypes in a population are associated with the basic strategies that are shaped by trial and error by a process of natural selection or learning. The natural selection process that determines how populations playing

specific strategies evolve is known as the replicator dynamics [12, 13, 16, 17] whose stable fixed points are Nash Equilibria (NE) [9]. The central equilibrium concept of evolutionary game theory is the notion of Evolutionary Stable Strategy (ESS) introduced by J. Smith and G. Price [11, 18]. An ESS is described as a strategy which has the property that if all the members of a population adopt it, no mutant strategy could invade the population under the influence of natural selection. ESS are interpreted as stable results of processes of natural selection.

Quantum games have proposed a new point of view for the solution of the classical problems and dilemmas in game theory. Quantum games are more efficient than classical games and provide a saturated upper bound for this efficiency [19, 20, 21, 22, 23, 24].

A Nash equilibrium is a set of strategies, one for each player, such that no player has an incentive to unilaterally change his action. Players are in equilibrium if a change in strategies by any one of them would lead that player to earn less than if he remained with his current strategy. A Nash equilibrium satisfies the following condition

$$E(p, p) \geq E(r, p), \quad (2)$$

where  $E(s_i, s_j)$  is a real number that represents the payoff obtained by a player who plays the strategy  $s_i$  against an opponent who plays the strategy  $s_j$ . A player can not increase his payoff if he decides to play the strategy  $r$  instead of  $p$ .

Consider a large population in which a two person game  $G = (S, E)$  is played by randomly matched pairs of animals generation after generation. Let  $p$  be the strategy played by the vast majority of the population, and let  $r$  be the strategy of a mutant present in small frequency. Both  $p$  and  $r$  can be pure or mixed. An evolutionary stable strategy (ESS)  $p$  of a symmetric two-person game  $G = (S, E)$  is a pure or mixed strategy for  $G$  which satisfies the following two conditions

$$E(p, p) > E(r, p),$$

$$\text{If } E(p, p) = E(r, p) \text{ then } E(p, r) > E(r, r). \quad (3)$$

Since the stability condition only concerns to alternative best replies,  $p$  is always evolutionarily stable if  $(p, p)$  is a strict equilibrium point. An ESS is also a Nash equilibrium since is the best reply to itself and the game is symmetric. The set of all the strategies that are ESS is a subset of the NE of the game. A population which plays an ESS can withstand an invasion by a small group of mutants playing a different strategy. It means that if a few individuals which play a different strategy are introduced into a population in an ESS, the evolutionarily selection process would eventually eliminate the invaders.

### 2. Evolution of a Socioeconomical System

Each agent in a n-player game where the  $i^{th}$  player has as strategy space  $S_i$  is modeled by a population of players

which have to be partitioned into groups. Individuals in the same group would all play the same strategy. Randomly we make play the members of the subpopulations against each other. The subpopulations that perform the best will grow and those that do not will shrink and eventually will vanish. The natural selection process assures survival of the best players at the expense of the others. The natural selection process that determines how populations playing specific strategies evolve is known as the replicator dynamics

$$\frac{dx_i}{dt} = [f_i(x) - \langle f(x) \rangle] x_i. \quad (4)$$

The probability of playing certain strategy or the relative frequency of individuals using that strategy is denoted by frequency  $x_i$ . The fitness function  $f_i = \sum_{j=1}^n a_{ij} x_j$  specifies how successful each subpopulation is,  $\langle f(x) \rangle = \sum_{k,l=1}^n a_{kl} x_k x_l$  is the average fitness of the population, and  $a_{ij}$  are the elements of the payoff matrix  $A$

$$\frac{dx_i}{dt} = \left[ \sum_{j=1}^n a_{ij} x_j - \sum_{k,l=1}^n a_{kl} x_k x_l \right] x_i. \quad (5)$$

The replicator dynamics rewards strategies that outperform the average by increasing their frequency, and penalizes poorly performing strategies by decreasing their frequency. The stable fixed points of the replicator dynamics are Nash equilibria, it means that if a population reaches a state which is a Nash equilibrium, it will remain there. It is important to note that the replicator dynamics is a vectorial differential equation while von Neumann equation can be represented in matrix form. If we would like to compare both systems the first we would have to do is to try to compare their evolution equations by trying to find a matrix representation of the replicator dynamics and this is

$$\frac{dX}{dt} = G + G^T, \quad (6)$$

where the relative frequencies matrix  $X$  has as elements  $x_{ij} = (x_i x_j)^{1/2}$  and

$$\begin{aligned} (G + G^T)_{ij} &= \frac{1}{2} \sum_{k=1}^n a_{ik} x_k x_{ij} \\ &+ \frac{1}{2} \sum_{k=1}^n a_{jk} x_k x_{ji} \\ &- \sum_{k,l=1}^n a_{kl} x_k x_l x_{ij} \end{aligned} \quad (7)$$

are the elements of the matrix  $(G + G^T)$ . Moreover, from this matrix representation we can find a Lax representation of the replicator dynamics [1]

$$\frac{dX}{dt} = [[Q, X], X] \quad (8)$$

and with  $\Lambda = [Q, X]$

$$\frac{dX}{dt} = [\Lambda, X]. \quad (9)$$

The matrix  $\Lambda$  is equal to

$$(\Lambda)_{ij} = \frac{1}{2} \left[ \left( \sum_{k=1}^n a_{ik} x_k \right) x_{ij} - x_{ji} \left( \sum_{k=1}^n a_{jk} x_k \right) \right] \quad (10)$$

and  $Q$  is a diagonal matrix which has as elements  $q_{ii} = \frac{1}{2} \sum_{k=1}^n a_{ik} x_k$ . If we take  $\Theta = [\Lambda, X]$  equation (9) becomes into  $\frac{dX}{dt} = \Theta$ , where the elements of the matrix  $\Theta$  are given by  $(\Theta)_{ij} = \frac{1}{2} \sum_{k=1}^n a_{ik} x_k x_{ij} + \frac{1}{2} \sum_{k=1}^n a_{jk} x_k x_{ji} - \sum_{k,l=1}^n a_{lk} x_k x_l x_{ij}$ . It is easy to realize that the matrix commutative form of the replicator dynamics (9) follows the same dynamic than the von Neumann equation (1). It can be shown that the properties of their correspondent elements (matrixes) are similar, being the properties corresponding to our quantum system more general than the classical system.

### C. Actual Relationships between Quantum Mechanics & Game Theory

The following table shows some specific resemblances between quantum statistical mechanics and evolutionary game theory.

Table 2

Quantum Statistical Mechanics	Evolutionary Game Theory
n system members	n population members
Each member in the state $ \Psi_k\rangle$	Each member plays strategy $s_i$
$ \Psi_k\rangle$ with $p_k \rightarrow \rho_{ii}$	$s_i \rightarrow x_i$
$\rho, \sum_i \rho_{ii} = 1$	$X, \sum_i x_i = 1$
$i\hbar \frac{d\rho}{dt} = [\hat{H}, \rho]$	$\frac{dX}{dt} = [\Lambda, X]$
$S = -Tr\{\rho \ln \rho\}$	$H = -\sum_i x_i \ln x_i$

Although a physical system is modeled and described mathematically through quantum mechanics while a socioeconomical is modeled through game theory both systems seem to have a similar behavior. Both are composed by  $n$  members (particles, subsystems, players, states, etc.). Each member of our systems is described by a state or a strategy which has assigned a determined probability. The quantum mechanical system is described by a density operator  $\rho$  whose elements represent the system average probability of being in a determined state. The socioeconomical system is described through a relative frequencies matrix  $X$  whose elements represent the frequency of players playing a determined strategy. The evolution equation of the relative frequencies matrix  $X$  (which describes our socioeconomical system) is given by a Lax form of the replicator dynamics which was shown that follows the same dynamic than the evolution equation of the density operator (i.e. the von Neumann equation).

### III. DIRECT CONSEQUENCES IN THE ANALOGOUS BEHAVIOR OF QUANTUM MECHANICS & GAME THEORY

#### A. Quantization Relationships

We can propose the next “quantization relationships”

$$\begin{aligned} x_i &\rightarrow \sum_{k=1}^n \langle i | \Psi_k \rangle p_k \langle \Psi_k | i \rangle = \rho_{ii}, \\ (x_i x_j)^{1/2} &\rightarrow \sum_{k=1}^n \langle i | \Psi_k \rangle p_k \langle \Psi_k | j \rangle = \rho_{ij}. \end{aligned} \quad (11)$$

A population will be represented by a quantum system in which each subpopulation playing strategy  $s_i$  will be represented by a pure ensemble in the state  $|\Psi_k(t)\rangle$  and with probability  $p_k$ . The probability  $x_i$  of playing strategy  $s_i$  or the relative frequency of the individuals using strategy  $s_i$  in that population will be represented as the probability  $\rho_{ii}$  of finding each pure ensemble in the state  $|i\rangle$  [1].

#### B. Quantum Replicator Dynamics

Through the last quantization relationships the replicator dynamics (in matrix commutative form) takes the form of the equation of evolution of mixed states i.e. the von Neumann equation is the quantum analogue of the replicator dynamics. And also  $X \rightarrow \rho$ ,  $\Lambda \rightarrow -\frac{i}{\hbar} \hat{H}$ , and  $H(x) \rightarrow S(\rho)$  [1, 3].

#### C. Quantum Games Entropy

Classically, the entropy of our system is given by

$$H = -Tr \{X \ln X\}. \quad (12)$$

When the non diagonal elements of matrix  $X$  are equal to zero it turns to the Shannon entropy over the elements of the relative frequency vector  $x$ , i.e.  $H = -\sum_{i=1}^n x_i \ln x_i$ . By supposing that the vector of relative frequencies  $x(t)$  evolves in time following the replicator dynamics (9) the evolution of the entropy of our system would be given by [3]

$$\frac{dH}{dt} = Tr \left\{ U(\tilde{H} - X) \right\}, \quad (13)$$

where  $U_i = [f_i(x) - \langle f(x) \rangle]$ , and  $\tilde{H}$  comes from  $H = Tr \tilde{H}$ .

The entropy of a quantum system is given by the von Neumann entropy

$$S(t) = -Tr \{ \rho \ln \rho \} \quad (14)$$

which in a far from equilibrium system also vary in time until it reaches its maximum value. When the dynamics is chaotic the variation with time of the physical entropy goes through three successive, roughly separated stages [25]. In the first one,  $S(t)$  is dependent on the details of the dynamical system and of the initial distribution, and no generic statement can be made. In the second stage,  $S(t)$  is a linear increasing function of time ( $\frac{dS}{dt} = \text{const.}$ ). In the third stage,  $S(t)$  tends asymptotically towards the constant value which characterizes equilibrium ( $\frac{dS}{dt} = 0$ ). With the purpose of calculating the time evolution of entropy we approximated the logarithm of  $\rho$  by series i.e.  $\ln \rho = (\rho - I) - \frac{1}{2}(\rho - I)^2 + \frac{1}{3}(\rho - I)^3 \dots$  and [3]

$$\begin{aligned} \frac{dS(t)}{dt} &= \frac{11}{6} \sum_i \frac{d\rho_{ii}}{dt} \\ &\quad - 6 \sum_{i,j} \rho_{ij} \frac{d\rho_{ji}}{dt} \\ &\quad + \frac{9}{2} \sum_{i,j,k} \rho_{ij} \rho_{jk} \frac{d\rho_{ki}}{dt} \\ &\quad - \frac{4}{3} \sum_{i,j,k,l} \rho_{ij} \rho_{jk} \rho_{kl} \frac{d\rho_{li}}{dt} + \zeta. \end{aligned} \quad (15)$$

#### D. Games Analysis from Quantum Information Theory

If we define an Entropy [2, 3, 26, 27, 28, 29, 30] over a random variable  $S^A$  (player's  $A$  strategic space) which can take the values  $s_i^A$  with the respective probabilities  $x_i^A$  i.e.  $H(A) \equiv -\sum_{i=1}^n x_i \log_2 x_i$ , we could interpret the entropy of our game as a measure of uncertainty before we learn what strategy player  $A$  is going to use [3]. If we do not know what strategy a player is going to use every strategy becomes equally probable and our uncertainty becomes maximum and it is greater while greater is the number of strategies. If we would know the relative frequency with which player  $A$  uses any strategy we can prepare our reply in function of the most probable player  $A$  strategy. That would be our actual best reply which in that moment would let us maximize our payoff due to our uncertainty. Obviously our uncertainty vanish if we are sure about the strategy our opponent is going to use. The complete knowledge of the rules of a game and the reserve in our strategies becomes an advantage over an opponent who does not know the game rules or who always plays in a same predictive way. To become a game fair, an external referee should make the players to know completely the game rules and the strategies that the players can use.

If player  $B$  decides to play strategy  $s_j^B$  against player  $A$  (who plays strategy  $s_i^A$ ) our total uncertainty about the pair  $(A, B)$  can be measured by an external “referee” through the joint entropy of the system  $H(A, B) \equiv -\sum_{i,j} x_{ij} \log_2 x_{ij}$ ,  $x_{ij}$  is the joint probability to find  $A$

in state  $s_i$  and  $B$  in state  $s_j$ . This is smaller or at least equal than the sum of the uncertainty about  $A$  and the uncertainty about  $B$ ,  $H(A, B) \leq H(A) + H(B)$ . The interaction and the correlation between  $A$  and  $B$  reduces the uncertainty due to the sharing of information. There can be more predictability in the whole than in the sum of the parts. The uncertainty decreases while more systems interact jointly creating a new only system.

We can measure how much information  $A$  and  $B$  share and have an idea of how their strategies or states are correlated by their mutual or correlation entropy  $H(A : B) \equiv -\sum_{i,j} x_{ij} \log_2 x_{ij}$ , with  $x_{ij} = \frac{\sum_i x_{ij} \sum_j x_{ij}}{x_{ij}}$ . It can be seen easily as  $H(A : B) \equiv H(A) + H(B) - H(A, B)$ . The joint entropy would equal the sum of each of  $A$ 's and  $B$ 's entropies only in the case that there are no correlations between  $A$ 's and  $B$ 's states. In that case, the mutual entropy vanishes and we could not make any predictions about  $A$  just from knowing something about  $B$ .

If we know that  $B$  decides to play strategy  $s_j^B$  we can determinate the uncertainty about  $A$  through the conditional entropy  $H(A | B) \equiv H(A, B) - H(B) = -\sum_{i,j} x_{ij} \log_2 x_{i|j}$  with  $x_{i|j} = \frac{x_{ij}}{\sum_i x_{ij}}$ . If this uncertainty is bigger or equal to zero then the uncertainty about the whole is smaller or at least equal than the uncertainty about  $A$ , i.e.  $H(A : B) \leq H(A)$ . Our uncertainty about the decisions of player  $A$  knowing how  $B$  and  $C$  plays is smaller or at least equal than our uncertainty about the decisions of  $A$  knowing only how  $B$  plays  $H(A | B, C) \leq H(A | B)$  i.e. conditioning reduces entropy. If the behavior of the players of a game follows a Markov chain i.e.  $A \rightarrow B \rightarrow C$  then  $H(A) \geq H(A : B) \geq H(A : C)$  i.e. the information can only reduces in time. Also any information  $C$  shares with  $A$  must be information which  $C$  also shares with  $B$ ,  $H(C : B) \geq H(C : A)$ .

Two external observers of the same game can measure the difference in their perceptions about certain strategy space of the same player  $A$  by its relative entropy. Each of them could define a relative frequency vector,  $x$  and  $y$ , and the relative entropy over these two probability distributions is a measure of its closeness  $H(x || y) \equiv \sum_i x_i \log_2 x_i - \sum_i x_i \log_2 y_i$ . We could also suppose that  $A$  could be in two possible states i.e. we know that  $A$  can play of two specific but different ways and each way has its probability distribution (again  $x$  and  $y$  that also is known). Suppose that this situation is repeated exactly  $N$  times or by  $N$  people. We can made certain "measure", experiment or "trick" to determine which the state of the player is. The probability that these two states can be confused is given by the classical or the quantum Sanov's theorem [27, 31, 32, 33].

By analogy with the Shannon entropies it is possible to define conditional, mutual and relative quantum entropies which also satisfy many other interesting properties that do not satisfy their classical analogues. For example, the conditional entropy  $S(A | B)$  can be negative and its negativity always indicates that two systems

(in this case players) are entangled and indeed, how negative the conditional entropy is provides a lower bound on how entangled the two systems are [34]. If  $\lambda_i$  are the eigenvalues of  $\rho$  then von Neumann's definition can be expressed as  $S(\lambda) = -\sum_i \lambda_i \ln \lambda_i$  and it reduces to a Shannon entropy if  $\rho$  is a mixed state composed of orthogonal quantum states [35]. Our uncertainty about the mixture of states  $S(\sum_i p_i \rho_i)$  should be higher than the average uncertainty of the states  $\sum_i p_i S(\rho_i)$ .

### E. Thermodynamical Temperature of a Socioeconomical System

By other hand, in statistical mechanics entropy can be regarded as a quantitative measure of disorder. It takes its maximum possible value  $\ln n$  in a completely random ensemble in which all quantum mechanical states are equally likely and is equal to zero if  $\rho$  is pure i.e. when all its members are characterized by the same quantum mechanical state ket. Entropy can be maximized subject to different constraints. Generally, the result is a probability distribution function. We maximize  $S(\rho)$  subject to the constraints  $\delta \text{Tr}(\rho) = 0$  and  $\delta \langle E \rangle = 0$  and the result is

$$\rho_{ii} = \frac{e^{-\beta E_i}}{\sum_k e^{-\beta E_k}} \quad (16)$$

which is the condition that the density operator must satisfy to our system tends to maximize its entropy  $S$ . Without the internal energy constraint  $\delta \langle E \rangle = 0$  we obtain  $\rho_{ii} = \frac{1}{N}$  which is the  $\beta \rightarrow 0$  limit ("high - temperature limit") in equation (16) in where a canonical ensemble becomes a completely random ensemble in which all energy eigenstates are equally populated. In the opposite low - temperature limit  $\beta \rightarrow \infty$  tell us that a canonical ensemble becomes a pure ensemble where only the ground state is populated [36]. The parameter  $\beta$  is related inversely to the "temperature"  $\tau$  of the system,  $\beta = \frac{1}{\tau}$ . We can rewrite entropy in function of the partition function  $Z = \sum_k e^{-\beta E_k}$ ,  $\beta$  and  $\langle E \rangle$  via  $S = \ln Z + \beta \langle E \rangle$ . From the partition function we can know some parameters that define the system like  $\langle E \rangle$  and  $\langle \Delta E^2 \rangle$ . We can also analyze the variation of entropy with respect to the average energy of the system

$$\frac{\partial S}{\partial \langle E \rangle} = \frac{1}{\tau}, \quad (17)$$

$$\frac{\partial^2 S}{\partial \langle E \rangle^2} = -\frac{1}{\tau^2} \frac{\partial \tau}{\partial \langle E \rangle} \quad (18)$$

and with respect to the parameter  $\beta$

$$\frac{\partial S}{\partial \beta} = -\beta \langle \Delta E^2 \rangle, \quad (19)$$

$$\frac{\partial^2 S}{\partial \beta^2} = \frac{\partial \langle E \rangle}{\partial \beta} + \beta \frac{\partial^2 \langle E \rangle}{\partial \beta^2}. \quad (20)$$

## F. The Applicability of Physics to Economics

Although both systems analyzed are described through two theories apparently different both are analogous and thus exactly equivalents. So, we could make use of some of the concepts, laws and definitions in physics for the best understanding of the behavior of economics and biology. Quantum mechanics could be a much more general theory that we had thought. It could encloses theories like games and evolutionary dynamics. From this point of view many of the equations, concepts and its properties defined quantically must be more general that its classical analogues.

It is important to remember that we are dealing with very general and unspecific terms, definitions, and concepts like state, game and system. Due to this, the theories that have been developed around these terms like quantum mechanics, statistical physics, information theories and game theories enjoy of this generality quality and could be applicable to model any system depending on what we want to mean for game, state, or system. Objectively these words can be and represent anything. Once we have defined what system is in our model, we could try to understand what kind of “game” is developing between its members and how they accommodate their “states” in order to get their objectives. This would let us visualize what temperature, energy and entropy would represent in our specific system through the relationships, properties and laws that were defined before when we described a physical system [4, 5, 6].

## G. The Collective Welfare Principle & the Quantum Understanding of Classical Systems

If our systems are analogous and thus exactly equivalents, our physical equilibrium (maximum entropy) should be also exactly equivalent to our socioeconomical equilibrium (NE or ESS). And if the natural trend of a physical system is to a maximum entropy state, should not a socioeconomical system trend be also to a maximum entropy state which would have to be its state of equilibrium? Has a socioeconomical system something like a “natural trend”?

Based specially on the analogous behavior between quantum mechanics and game theory, it is suggested the following (quantum) understanding of our (classical and/or socioeconomical) system: If in an isolated system each of its accessible states do not have the same probability, the system is not in equilibrium. The system will vary and will evolve in time until it reaches the equilibrium state in where the probability of finding the system in each of the accessible states is the same. The system will find its more probable configuration in which the number of accessible states is maximum and equally probable. The whole system will vary and rearrange its state and the states of its ensembles with the purpose of maximize its entropy and reach its equilibrium state.

We could say that the purpose and maximum payoff of a physical system is its maximum entropy state. The system and its members will vary and rearrange themselves to reach the best possible state for each of them which is also the best possible state for the whole system.

This can be seen like a microscopical cooperation between quantum objects to improve their states with the purpose of reaching or maintaining the equilibrium of the system. All the members of our quantum system will play a game in which its maximum payoff is the equilibrium of the system. The members of the system act as a whole besides individuals like they obey a rule in where they prefer the welfare of the collective over the welfare of the individual. This equilibrium is represented in the maximum entropy of the system in where the system resources are fairly distributed over its members. The system is stable only if it maximizes the welfare of the collective above the welfare of the individual. If it is maximized the welfare of the individual above the welfare of the collective the system gets unstable and eventually it collapses (Collective Welfare Principle) [1, 3, 4, 5, 6, 7].

## IV. THE EQUILIBRIUM PROCESS CALLED GLOBALIZATION

Lets discuss how the world process that it is called “globalization” has a behavior exactly equivalent to a system that is tending to a maximum entropy state.

### A. Globalization

Globalization represents the inexorable integration of markets, nation-states, currencies, technologies [37] and the intensification of consciousness of the world as a whole [38]. This refers to an increasing global connectivity, integration and interdependence in the economic, social, technological, cultural, political, and ecological spheres [39]. Globalization has various aspects which affect the world in several different ways such as [39] the emergence of worldwide production markets and broader access to a range of goods for consumers and companies (industrial), the emergence of worldwide financial markets and better access to external financing for corporate, national and subnational borrowers (financial), the realization of a global common market, based on the freedom of exchange of goods and capital (economical), the creation of a world government which regulates the relationships among nations and guarantees the rights arising from social and economic globalization (political) [40], the increase in information flows between geographically remote locations (informational), the growth of cross-cultural contacts (cultural), the advent of global environmental challenges that can not be solved without international cooperation, such as climate change, cross-boundary water and air pollution, over-fishing of the ocean, and the spread of invasive species (ecological)

and the achievement of free circulation by people of all nations (social).

### 1. *Economical Globalization*

In economics, globalization is the convergence of prices, products, wages, rates of interest and profits towards developed country norms [41]. Globalization of the economy depends on the role of human migration, international trade, movement of capital, and integration of financial markets. Economic globalization can be measured around the four main economic flows that characterize globalization such as goods and services (e.g. exports plus imports as a proportion of national income or per capita of population), labor/people (e.g. net migration rates; inward or outward migration flows, weighted by population), capital (e.g. inward or outward direct investment as a proportion of national income or per head of population), and technology. To what extent a nation-state or culture is globalized in a particular year has until most recently been measured employing simple proxies like flows of trade, migration, or foreign direct investment, as described above. A multivariate approach to measuring globalization is the recent index calculated by the Swiss Think tank KOF [42]. The index measures the three main dimensions of globalization: economic, social, and political.

### 2. *Big Communities & Strong Currencies*

Maybe the firsts of these so called states-nations, communities, “unions”, common markets, etc. were the United States of America and the USSR (now the Russian Federation). Both consists in a set or group of different nations or states under the same basic laws or principles (constitution), policies, objectives and an economy characterized by a same currency. Although each state or nation is a part of a big community each of them can take its own decisions and choose its own way of government, policies, laws and punishments (e.g. death penalty) but subject to a constitution (which is no more than a “common agreement”) and also subject to the decisions of the “congress” of the community which regulates the whole and the decisions of the parts. The United States of America consists in 50 states and a federal district. It also has many dependent territories located in the Antilles and Oceania. The currency in The United States is the Dollar. The Russian Federation consists in a big number of political subdivisions (88 components). There are 21 republics inside the federation with a big degree of autonomy over most of the aspects. The rest of territory consists in 48 provinces known as *óblast* and six regions (*kray*), between which there are 10 autonomic districts and an autonomic *óblast* and 2 federal cities (Moscow and San Petersburg). Recently, seven federal districts have been added. The currency in Russia is the Rublo

[39].

The European Union stands as an example that the world should emulate by its sharing rights, responsibilities, and values, including the obligation to help the less fortunate. The most fundamental of these values is democracy, understood to entail not merely periodic elections, but also active and meaningful participation in decision making, which requires an engaged civil society, strong freedom of information norms, and a vibrant and diversified media that are not controlled by the state or a few oligarchs. The second value is social justice. An economic and political system is to be judged by the extent to which individuals are able to flourish and realize their potential. As individuals, they are part of an ever-widening circle of communities, and they can realize their potential only if they live in harmony with each other. This, in turn, requires a sense of responsibility and solidarity [43].

The meeting of 16 national leaders at the second East Asia Summit (EAS) on the Philippine island of Cebu in January 2007 offered the promise of the politically fractious but economically powerful Asian mega-region one day coalescing into a single meaningful unit [44].

Seth Kaplan has offered the innovative idea of a West African Union (the 15 West African countries stretching from Senegal to Nigeria) to help solve West Africa’s deep-rooted problems [45].

In South America has been proposed the creation of a Latin-American Community which is an offer for the integration, the struggle against the poverty and the social exclusion of the countries of Latin-America. It is based on the creation of mechanisms to create cooperative advantages between countries that let balance the asymmetries between the countries of the hemisphere and the cooperation of funds to correct the inequalities of the weak countries against the powerful nations. The economy ministers of Paraguay, Brazil, Argentina, Ecuador, Venezuela and Bolivia agreed in the “Declaración de Asunción” to create the Bank of the South and invite the rest of countries to add to this project. The Brazilian economy minister Mantega stand out that the new bank is going to consolidate the economic, social and politic block that is appearing in South America and now they have to point to the creation of a common currency. Recently, Uruguay has also accepted the offer of the creation of the bank and the common currency and is expected that more countries add to this offer [46].

## B. The Equilibrium Process

After analyzing our systems we concluded that a socioeconomic system has a behavior exactly equivalent that a physical system. Both systems evolve in analogous ways and to analogous states. A system where its members are in Nash Equilibrium (or ESS) is exactly equivalent to a system in a maximum entropy state. The stability of the system is based on the maximization of

the welfare of the collective above the welfare of the individual. The natural trend of a physical system is to a maximum entropy state, should not a socioeconomical system trend be also to a maximum entropy state which would have to be its state of equilibrium? Has a socioeconomical system something like a “natural trend”?

From our analysis a population can be represented by a quantum system in which each subpopulation playing strategy  $s_i$  will be represented by a pure ensemble in the state  $|\Psi_k(t)\rangle$  and with probability  $p_k$ . The probability  $x_i$  of playing strategy  $s_i$  or the relative frequency of the individuals using strategy  $s_i$  in that population will be represented as the probability  $\rho_{ii}$  of finding each pure ensemble in the state  $|i\rangle$ . Through these quantization relationships the replicator dynamics (in matrix commutative form) takes the form of the equation of evolution of mixed states i.e. the von Neumann equation is the quantum analogue of the replicator dynamics.

Our now “quantum statistical” system composed by quantum objects represented by quantum states which represent the strategies with which “players” interact is characterized by certain interesting physical parameters like temperature, entropy and energy and has a similar or analogous behavior.

In this statistical mixture of ensembles (each ensemble is characterized by a state and each state has assigned a determined probability) its natural trend is to its maximum entropy state. If each of its accessible states do not have the same probability, the system will vary and will evolve in time until it reaches the equilibrium state in where the probability of finding the system in each of the accessible states is the same and its number is maximum. In this equilibrium state or maximum entropy state the system “resources” are fairly distributed over its members. Each ensemble will be equally probable, will be characterized by a same temperature and in a stable state.

Socioeconomically and based on our analysis, our world could be understood as a statistical mixture of “ensembles” (countries for example). Each of these ensembles are characterized by a determined state and a determined probability. But more important, each “country” is characterized by a specific “temperature” which is a measure of the socioeconomical activity of that ensemble. That temperature is related with the activity or with the interactions between the members of the ensemble. The system will evolve naturally to a maximum entropy state. Each pure ensemble of this statistical mixture will vary and accommodate its state until get the “thermal equilibrium” first with its nearest neighbors creating new big ensembles characterized each of them by a same temperature. Then with the time, these new big ensembles will seek its “thermal equilibrium” between themselves and with its nearest neighbors creating new bigger ensembles. The system will continue evolving naturally in time until the whole system get an only state characterized by a same “temperature”.

This behavior is very similar to what has been called

globalization. The process of equilibrium that is absolutely equivalent to a system that is tending to a maximum entropy state is the actual globalization. This analysis predicts the apparition of big common “markets” or (economical, political, social, etc.) communities of countries (European Union, Asian Union, Latin-American Community, African Union, Mideast Community, Russia and USA) and strong common currencies (dollar, euro, yen, sol, etc.). The little and poor economies eventually will be unavoidably absorbed by these “markets” and these currencies. If this process continues these markets or communities will find its “equilibrium” by decreasing its number until reach a state in where there exists only one big common community (or market) and only one common currency around the world.

## V. CONCLUSIONS

Although both systems analyzed are described through two theories apparently different (quantum mechanics and game theory) both are analogous and thus exactly equivalents. A socioeconomical system has a behavior exactly equivalent that a physical system. Both systems evolve in analogous ways and to analogous points. The quantum analogue of the replicator dynamics is the von Neumann equation. A system where its members are in Nash Equilibrium (or ESS) is exactly equivalent to a system in a maximum entropy state. The natural trend of both systems is to its maximum entropy state which is its state of equilibrium.

The so called “globalization” process (i.e. the inexorable integration of markets, currencies, nation-states, technologies and the intensification of consciousness of the world as a whole) has a behavior exactly equivalent to a system that is tending to a maximum entropy state. This globalization process obeys a collective welfare principle in where the maximum payoff is given by the equilibrium of the system and its stability by the maximization of the welfare of the collective over the individual welfare. This let us predict the apparition of big common markets and strong common currencies that will reach the “equilibrium” by decreasing its number until they get a state characterized by only one common currency and only one big common community around the world.

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